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Software for Geodynamical Researches Used in the LSGER IAA

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Abstract. Software used in the Laboratory of Space Geodesy and Earth Rotation (LSGER) of the Institute of Applied Astronomy (IAA) of the Russian Academy of Sciences for computation of geodynamical products: Earth Orientation Parameters (EOP) and station coordinates (TRF) based on observations of space geodesy techniques (VLBI, SLR) is described. The principal software components used for these investigations are GROSS for processing of SLR observations; Bernese for processing of GPS observations; OCCAM for processing of VLBI observations; and software for data exchange.

1. Introduction

The IAA is responsible for applications and development of space geodesy methods for geodynamical research. In this framework, the Laboratory of Space Geodesy and Earth Rotation (LSGER) has been working in the following fields:

1. Development of algorithms and software for processing of VLBI, SLR and GPS observations,
2. Investigation and improvement of the dynamic models for precise calculations of satellite orbits,
3. Computation of EOP from SLR observations,
4. Computation of EOP, station and radio source coordinates from VLBI observations,
5. Computation of EOP and station coordinates from GPS observations.
6. Combining VLBI, SLR, GPS observations for determination of EOP and station coordinates,
7. Investigations of regional crust deformation in the framework of regional geodynamical projects,
8. Support and investigation of local geodetic networks at QUASAR network sites.

The main software products used in the LSGER to support research activity in these topics are briefly reviewed in this paper.

2. GROSS Package

The GROSS package is designed mainly for the analysis of the SLR observations and the analysis of EOP and TRF series. It runs on PCs under MS DOS/Windows.

The GROSS package is used for the analysis of the observations collected by the global SLR network in cooperation with IERS, including participation in the IERS Rapid Service, and for own investigations. This began in 1995. The special strategy of operational calculations of EOP has been developed to minimize the gap between last observation and the epoch of operational EOP (this gap is now about 2 days).

Operational calculations of EOP are made every working day automatically. The systems used for operational computations include MS DOS/Windows (GROSS, data formatting, supplement service programs, archiving of results) and Unix (data exchange with world data bases and centers of analysis, ftp functions). Interaction between Windows and Unix components is done via Windows's network SMB protocol. This is implemented on Unix by a `samba` server.

The software works as follows. Observational data and other relevant files from Data Centers are automatically downloaded to the Unix machine. These data are picked up by GROSS as as scheduled task. Upon completion of the computation, the resulting output file is transferred to the Unix machine where it is automatically sent to users. In parallel, EOP files for common IAA use are updated along with the corresponding data base on both Windows and Unix machines. These data are available via anonymous ftp as well.

Before and during computation GROSS controls input data to prevent incorrect results if these data are incomplete or incorrect. Some configuration parameters needed for GROSS are automatically adjusted dependent on the amount and quality of input data.

3. MAL Library

Together with the GROSS package the MAL (Mathematical and Astronomy Library) library is being developed. MAL contains more than 700 mathematical, astronomical, geodetic, and service Fortran routines of common use. Routines are written in Fortran 77 with some Fortran 90 extensions.

One of the most difficult problems during the design of a S/W package is portability between platforms. It is impossible to create such software using only standard operators (at least in Fortran). Many needed functions such as file operations, reading the command line, getting system information, etc., can be only be achieved with the use of RunTime libraries associated with each compiler. This requires changing many subroutine calls when changing platforms.

The following strategy has been used to solve this problem without the need of changing code in the main programs or routines.

All functions requiring system operators are implemented by a set of about 30 special system dependent routines with special names. These routines contain calls to RunTime library functions. Most of these routines depend on only the platform while some also depend on the compiler.

A programmer uses these routines in his software instead of the RunTime library. A collection of such routines for various compilers makes installation on each platform simple. To compile the main part of MAL a user needs to add several system depending routines for the given platform/compiler without the need to review the complete package.

Unfortunately, the serious limitation in the use of the MAL library is that all documentation is available only in Russian (although the in-code comments are in English).

4. OCCAM Package

The OCCAM package has been developed for geodetic VLBI analysis. It was originated by a group of West-European scientists (H. Schuh, N. Zarraoa, and others). The package has been intensively modified and improved by the IAA and the St. Petersburg State University. OCCAM is a compact and portable package providing high precision determination of EOP and station coordinates.

The package runs on a PC under MS DOS/Windows. The main feature of OCCAM is the use of the Kalman filter technique for tropospheric zenith delay and clock offset estimation that is modeled as random walk stochastic process.

The package has been used for routine processing of VLBI observations collected from the global VLBI network from 1997 onward. Solutions are regularly submitted to IERS and used for computation of the IERS operational and final combined products.

5. Bernese Package

Bernese has been developed by the Astronomical Institute of the University of Bern. It is widely known as one of the most powerful, flexible, and accurate software for processing of GPS observations. It provides computation of EOP, station coordinates and atmospheric parameters (both troposphere and ionosphere).

We use Bernese mainly for the analysis of observations from regional GPS networks, such as the Baltic Sea Level project. Routine processing of the EUREF network is under testing.

In exploring the use of Bernese in the LSGER we encountered some problems related to the automate computation and integrating Bernese with other software used for geodynamical researches.

Bernese consists of a set of a command-line utilities, which implement the processing algorithms, and a text-mode "menu" frontend. There is also an automation layer on top of this frontend.

To facilitate direct integration of our custom processing libraries with Bernese, and to make the automation of processing more flexible, a special software package to control Bernese usage has been developed.

6. PyGPS Package

PyGPS is a software package aimed at the high level control and automation of GPS processing with the use of Bernese v. 4.0. Its core language is Python, although some components are written in C and Fortran and implemented as Python extension modules.

In brief, the package consists of some general purpose modules, not necessary related to Bernese, and a wrapper over the MAIN subsystem of the Bernese software. General purpose modules deal with GPS date and time arithmetic, RINEX files, and the data processing library MAL. The Bernese-related part of the package exploits heavily the object-oriented features of the Python language, and a programmer is encouraged to build his/her own class hierarchies based on the core classes. These would incorporate his/her own experience with particular sets of processing parameters, occurred suitable in some particular situations.

The original contribution to the overall processing strategy, which utilizes PyGPS, includes a special iteration loop, aimed at the creation of a set of baselines together with their preprocessing and ambiguity resolution. This step is described in a special issue of the proceedings of the Finnish Geodetic Institute.

7. Transfer Data through Internet over Unstable Connections

The subroutine package "aftp" includes the utilities and libraries for automating the download of the results of VLBI and SLR observations from some astronomical data servers (USNO, CDDIS, EDC).

The basic functionality of the package is based upon a finite automaton schema, which implements a robust self-recovering process of background data transfer over unstable connections. Whenever a new portion of data or a control protocol response is expected, the corresponding timeout is checked, and an attempt to re-establish the connection is made after a reasonable time. This is expressed as the automaton moving from one state to another. The "memory" of the described automaton is the sequence of data chunks (most frequently files) yet to download or upload. This queue is automatically updated during the transfer, so that after any system crash the process can be resumed correctly.

A universal utility to download an arbitrary collection of files from an arbitrary ftp server is also implemented. It takes a list of files, where first the two lines describe the server access and the common remote directory for all the files. This file serves as a "file queue" for the automaton described above.

8. Conclusion

The Laboratory of Space Geodesy and Earth Rotation of the Institute of Applied Astronomy RAS possesses the complete set of software needed for the analysis of modern space geodesy observations – VLBI, SLR, GPS. All software is actively used for scientific research, usually in the framework of international programs and projects coordinated by IERS and IAG. A high degree of automation of routine computations provides routine and reliable results and saves much staff time.